

Field Trial of a System to Obtain Data on Population Exposure to X-rays

JOSEPH N. GITLIN, B.A., CHARLES R. HAYMAN, M.D., E. GENE PROCTOR, B.S.
and PAUL L. RONEY, B.A.

THE USE of X-ray equipment in the healing arts has been identified (1-5) as an important segment of the total exposure of the U.S. population to radiation. The need to develop programs to promote more efficient use of X-ray equipment and reduce or eliminate unnecessary exposure to X-radiation has been documented in both Congressional testimony and professional publications (3, 4, 6-8). Accordingly, the Public Health Service is engaged in activities ranging from the financial support of basic research to the promotion of surveys of clinical facilities and equipment through State and local health departments.

The growing interest in obtaining basic information on this subject is reflected by an increasing number of studies aimed at providing reliable estimates of the magnitude and distribution of population exposure to X-radiation. These include research on doses to specific body areas and studies of doses associated with selected X-ray examinations and procedures (9-13).

Mr. Gitlin is public health analyst and Mr. Roney is supervisory statistician, Technical Operations Branch, Division of Radiological Health, Public Health Service. Dr. Hayman is medical director and Mr. Proctor is industrial hygienist, region VI, Pennsylvania Department of Health. Assisting in the field trial were Dr. James Miller, Medical X-Ray Project, Dr. Theodore Ditchek, X-Ray Exposure Control Laboratory, and other members of the State Assistance Branch, Division of Radiological Health.

Other studies conducted in several communities have indicated that estimates of population exposure to X-rays can be derived from medical and dental records (6, 14). The U.S. National Health Survey's recent report, "Volume of X-Ray Visits" (15), demonstrated the feasibility of obtaining X-ray visit data from a sample of the U.S. population by household interviews. A pilot study conducted by the Division of Radiological Health, Public Health Service, in Montgomery County, Md., showed that visit data could be used as a basis for obtaining exposure information from X-ray facilities.

In December 1962, a preliminary design for a system to obtain data on population exposure to X-rays was prepared by the division. The protocol included a household interview survey followed by a mail questionnaire to X-ray facilities. As a result, the division made tentative arrangements with the U.S. National Health Survey to repeat the X-ray visit questions in the household survey to be conducted April through June 1964. In addition, arrangements were made with the Pennsylvania Department of Health to conduct a field trial during the summer of 1963 to test the methods and procedures planned for the national study.

Berks County, Pa., was selected as the site of the field trial because (a) it had the desired urban-rural and socioeconomic characteristics considered necessary for testing the followup procedures, (b) it was convenient to the Public Health Service—Division of Radiological Health Laboratory at Rockville, Md., and (c)

cooperation of the State health department and its regional office was assured because of special interest in the subject. Cooperation was essential in planning and coordinating the field trial, particularly with the local medical and dental associations.

Berks County is located in southeastern Pennsylvania. The county seat, Reading, is 125 miles from Rockville, 3½ hours travel by automobile. The county has a population of 275,000, of whom 98,000 live in Reading and 79,000 in other urban areas. Some 11,000 reside in rural towns of 1,000 to 2,500, and 87,000 in smaller communities. There are numerous sites with heavy and light industry, rapidly growing suburbs, and completely rural areas. The population distribution is similar to that of the State, except that the county has only 4,700 nonwhite persons, of whom 4,170 live in Reading.

The county has three general hospitals, with X-ray departments served by seven full-time radiologists. There are two other radiologists practicing in private offices. Additional professionals in private practice with their own diagnostic X-ray equipment are as follows: 30 of 250 physicians, 150 of 160 dentists, 9 of 14 chiropractors, 12 of 17 chiroprodists, and 1 of 19 osteopaths.

The county is 1 of 12 in region VI of the Pennsylvania Department of Health. The regional office, located in West Reading, and the central office in Harrisburg conduct specialized public health programs, including radiological health, in the counties. The county health center is staffed with State public health nurses, sanitarians, and clerks. Additional local services in nursing and sanitation are provided in Reading by the city health department.

The regional medical director was interested in participating in this field research for its stimulating effect on the regional and county staffs. Five studies on other subjects are currently in progress in the region. The State health department wanted to know the current status of X-ray facilities because its industrial hygienists had been inspecting X-ray installations throughout the past 3 years. Eighty-five percent of the facilities had been surveyed, and recommendations for necessary corrections had been made.

Objectives and Design

The specific objectives of the field trial were to obtain data about X-ray visits from selected households in the county and, for each reported visit, to obtain and evaluate exposure data from the designated X-ray facilities. An X-ray visit was defined as a visit by an individual to a facility when X-ray equipment was used for diagnosis or treatment of the individual. An X-ray facility was defined as an office, hospital, clinic, or mobile unit where X-ray equipment is used for diagnosis or treatment (15).

The field trial was designed in three phases. The first was a household interview survey to obtain data on the X-ray visit experience of each household member during the 3-month period preceding the interview. The second phase was a followup request, consisting of a report form and film pack, mailed to each X-ray facility at which a reported X-ray visit occurred. In the third phase, Public Health Service personnel visited the participating X-ray facilities and interviewed physicians, dentists, and technicians to obtain their comments on the report form and film pack. An offer to survey the X-ray equipment at these facilities was included in this phase at the request of the Pennsylvania Department of Health.

Household Interview Survey

Since it was planned that the National Health Survey would collect the basic X-ray visit data in the proposed national study, the NHS questionnaire was adapted for use in the field trial. The questionnaire, adapted by the Division of Radiological Health with the cooperation of the NHS staff, was designed to report information on the household interviewed and for each member of the household; the reason for noninterview, if any; age, race, sex, marital status, education, and work status; and data on X-ray visits occurring during the 3 months preceding the interview. The X-ray visit data included type of visit (medical or dental), number of visits, type of examination or procedure (radiographic, fluoroscopic, or therapeutic), and parts of body X-rayed. In order to follow the reported X-ray visits, three items were added to the original format: height and weight of persons for whom medical X-rays



At each home the interviewer asked a qualified adult about X-ray visits of household members.

were reported, name and address of X-ray facility, and permission to contact the facility for exposure data related to the reported visit.

After adapting the household interview questionnaire for the field trial, division and NHS personnel wrote an Interviewer's Instruction Manual, which closely followed established National Health Survey procedures. Introductory and thank-you letters were also prepared for delivery to each selected household.

Sample Selection

A primary consideration in the household interview survey was to choose households with varying socioeconomic characteristics. Five census tracts, described by the Bureau of the Census (16), were picked to include various income, education, and urban-rural characteristics. Clusters of households were selected in each census tract, and within each cluster individual households were selected at random. This approach approximated the sampling procedures used by the National Health Survey.

The names and addresses of 47 persons in the survey area who experienced selected types of X-ray examinations or procedures during the 3-month reference period were added to the sample. These addresses were merged with the other selected households to insure the inclusion of relatively infrequent types of X-ray examinations in the test. The household interviewers did not know that known cases were added to the list of households.

Local Arrangements

In May 1963, Dr. Charles R. Hayman, the regional medical director, visited several local radiologists to inform them of the study. They presented the proposal to the executive committee of the county medical society and later gave detailed consultation and advice on the procedures and questionnaires to be used. Hayman next visited the presidents of the medical, dental, and osteopathic societies to inform them of the study. To simulate conditions of a national study, no public announcements were made by the sponsoring agencies.

Hayman and E. Gene Proctor, the regional industrial hygienist, traveled to the Radiological Health Laboratory in Rockville to discuss the operational plans and to suggest modifications for local conditions. They also advised the division staff on selection of suitable geographic areas within the county for household interviews. Desk space and telephone service were provided in the regional office for the division's interviewers. The medical director obtained from the departments of radiology of the three local hospitals lists of patients known to have received selected types of X-ray examinations or procedures within the study period. These were added to the sample selected from the census tracts. During the trial, liaison between Rockville and West Reading was maintained by a division representative stationed in the regional office.

Collection of Data

The household interview phase was conducted from June 17 to 28, 1963. The data were collected by six interviewers who had experience in Census Bureau or National Health Survey techniques and who received special training for the field trial. Consultation and assistance were provided by the NHS staff throughout this stage.

At each household the interviewer asked a qualified adult respondent to supply the requisite information for himself, for children, and for related adults who were not at home. All unrelated adults were interviewed concerning their own experiences. When an X-ray visit was reported, the interviewer also requested permission to seek further information from the X-ray facility.

Mail Followup of Reported Visits

After completion of the household interview phase, followup requests were mailed to the facilities where the reported X-ray visits took place. The purpose of this phase was to test the feasibility of using mail questionnaires to obtain X-ray exposure information which could not be supplied by household respondents. If a person reported multiple X-ray visits to a particular facility, the visits were included in a single request to minimize the number sent to a given facility. This explains the "person-facility" concept referred to subsequently.

Because of the relatively intensive coverage of the small geographic area and the addition of known hospital cases to the sample, an unusually large number of visits to the three local hospitals were reported. To minimize the hospital workload, the division agreed with the regional medical director that no more than three followup requests would be mailed to a single facility. Accordingly, a special control record was established for each facility. For the remaining cases the regional industrial hygienist arranged for division personnel to provide on-site assistance in recording the desired information.

To collect exposure information from the X-ray facilities, two report forms were designed by the Division of Radiological Health in consultation with the National Health Survey, Johns Hopkins University, and the Pennsylvania Department of Health. One report form was designed for medical examinations or procedures and the other for dental. Two film packs were also developed and used as a quality control of the exposure factors entered on the report forms.

Medical Report Forms

The medical report form was designed to cover all reported X-ray visits except dental. The first section of the form contained patient identification: name, age, sex, height, and weight. The last two items were added from the household questionnaire to permit more accurate estimates by physicians or technicians if exposure factors had not been recorded during the patient's visit.

The second section provided for recording the number and date of each X-ray visit by the named individual during the reference period. This information was checked against the X-ray visits reported on the household interview questionnaire.

The third section was designed for reporting data on each specific examination or procedure performed during the visit. This provided for a description of the examination or procedure, identification of the equipment used, and recording of the associated exposure factors. These factors included projection or view, distance, kilovoltage, milliamperage, time, type and size of film, type of screen or grid, and a question on additional patient protection.

In the fourth section, space was provided for comments by the physician or technician, and the final section of the form was designed for reporting pertinent data on X-ray therapy.

Dental Report Form

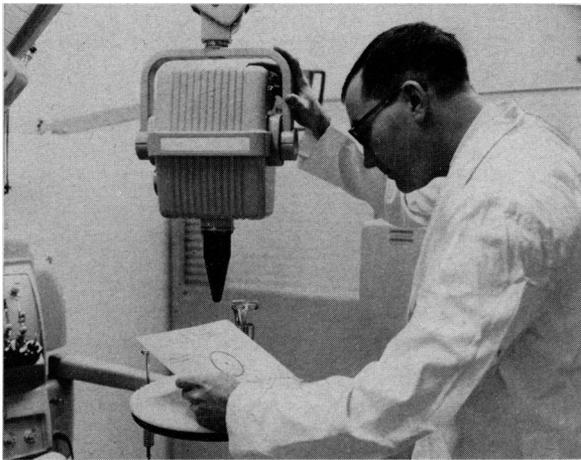
The dental report form followed the same general format of the medical form with one exception. Exposure data for groups of films could be reported as a single entry to accommodate the instances when many dental films are taken using identical factors.

Film Packs

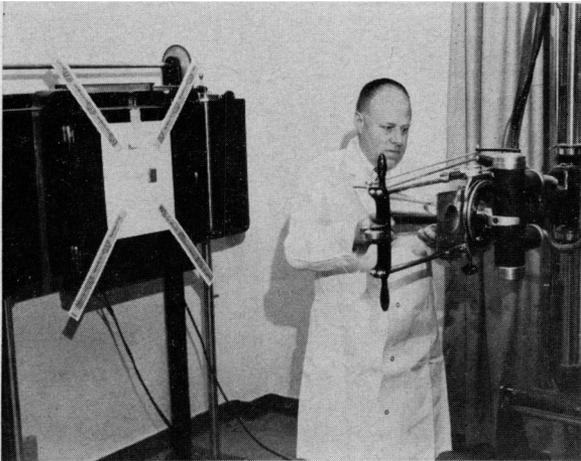
The film packs used in the field trial were experimental models developed for quality control of the data recorded on the report forms. The packs were designed specifically for diagnostic radiographic units to test the reliability of and to supplement the reported information related to machine output and beam quality, size, and angulation. A technical description of the film packs, including procedures for using them, is to be published separately. Details of procedures employed in the equipment survey are also to be published separately. This information may be requested from the Division of Radiological Health.

Letters for X-ray Facilities

Two introductory letters, one specifically for medical facilities and the other for dental facilities, were designed to accompany the follow-



After positioning the dental film pack under the pointer cone, the dentist exposed the pack for 1 second.



The medical film pack was exposed using parameters and machine factors identical to those used in the first exposure of the reported examination.

up requests. In addition to explaining the nature and purpose of the survey and use of accompanying report forms and film pack, the letters advised the practitioners that permission had been obtained from the household respondents to report the requested data to the Public Health Service. The letters stated that all information pertaining to individual patients would be treated confidentially and only statistical summaries would be published. A thank-you letter was sent to the participating X-ray facility upon receipt of a reply to the

followup request. This letter mentioned that the practitioner would be contacted by a Public Health Service X-ray survey team who would invite comments regarding the report forms and film pack. It also stated that the team was prepared to conduct an equipment survey if the practitioner so desired.

Visits to Participating X-ray Facilities

The regional industrial hygienist arranged for a division team to visit participating X-ray facilities to obtain comments of physicians, dentists, and technicians on the letters, report forms, and film packs used in the trial. An interview questionnaire was designed to record these comments. During these visits, X-ray equipment surveys were performed which provided pertinent information on physical characteristics of the X-ray machines as well as information on techniques and procedures generally used by the physician, dentist, or technician.

Summary of Findings

During the household interview survey, completed interviews were obtained from 289 households, containing 1,034 persons. The non-response rate was less than 2 percent of the



During visits to the participating facilities one Public Health Service team member surveyed equipment while the other obtained the practitioner's comments on the report form and the film pack.

households. A total of 446 X-ray visits were reported for the 3-month reference period preceding the week of the interviews. These visits involved 206 different individuals, including those reporting visits to both medical and dental facilities. Seventy-six visits to dental facilities were reported for 72 persons, and 370 visits to medical facilities were reported for 143 individuals. Households containing a known hospital case accounted for 254 visits of which the known cases alone contributed 203 visits. Of the 143 persons reporting medical visits, 44 reported more than one. Of the 72 reporting dental visits, 2 reported more than one.

The 206 persons with reported X-ray visits accounted for a total of 227 person-facility visits to 59 different facilities. These included 8 hospitals (5 outside Berks County), 13 medical offices (including 1 podiatrist), 35 dental offices, and 3 mobile units. The hospitals accounted for 81 person-facility visits of which 36 were known X-ray cases. Medical offices had 23 visits; dental facilities, 72; and mobile units, 51.

For the 227 person-facility visits reported, 165 followup requests were sent to 56 facilities. Separate requests were not sent to the three mobile units; these were handled through the sponsoring agencies. The 51 mobile unit visits were confirmed by comparing the schedule of the units with the dates and locations reported by the household respondents. Eleven person-facility visits were excluded from the mail followup procedure because no more than three such requests were sent to any facility.

Of the 165 followup requests initiated, a response was received for 152, or 92 percent. The 56 different facilities included 52 which responded with completed forms or an indication that the reported visit was prior to the reference period, no record of the patient, or no X-ray equipment. In addition to the four nonresponding facilities, four others did not complete all followup requests sent.

All eight hospitals responded adequately to the initial mail followup requests. Public Health Service personnel assisted the three local hospitals in completing followup on cases in excess of three. Of the 13 medical offices included in the survey, 6 returned completed forms, 2 reported they performed only fluoro-

scopic examinations, 1 reported no X-ray equipment, 1 reported patient refusal, and 3 did not respond. Of the 35 dental offices, 34 responded to the mail followup requests. Six of these indicated that the reported visit preceded the reference period.

One hundred film packs were received in response to followup requests. These included 37 from dental facilities and 63 from medical facilities, of which 46 were from the 3 local hospitals. Data from 14 medical film packs and 3 dental film packs were excluded because the visit did not occur during the survey period, the X-ray units used phototimers, or films were double exposed or unexposed. The small sample size precluded an analysis of the data by part of body exposed or type of examination or procedure performed.

A Division of Radiological Health team conducted an equipment survey in 43 of the 44 facilities visited. Most X-ray units surveyed were operating well within NBS Handbook 76 standards (17). These findings reflect the efforts of the 3-year program sponsored by the Pennsylvania Department of Health to promote conformance with established standards. At present, the findings of the equipment survey are being compared with previous State findings. A followup letter is being sent to each facility by the regional industrial hygienist, advising the practitioners of the survey results.

To compare exposure data, machine output at the film was calculated using selected data recorded on the medical report forms. These calculations were based on total filtration, kilovolt peak, milliamperere seconds, and target-to-film distance. For dental visits, output per second at the end of the pointer cone was calculated for comparability with film pack and equipment survey data.

Estimates of machine output obtained from the medical report forms and film packs showed a highly significant correlation ($r=0.94$). The report form data indicated a mean output at the film of 335 milliroentgens (mr) as compared with 301 mr from the film packs. Estimates of the amount of filtration in the primary beam, obtained from the medical report forms, film packs, and equipment surveys, were closely related. In only two instances did the filtration

indicated by the film pack differ by more than 0.5 mm from that recorded on the report forms.

Estimates of machine output from dental X-ray machines were obtained from all three sources described previously. A significant correlation ($r=0.58$) was observed between report form and film pack data. The mean output at the end of the pointer cone was 1.27 roentgens calculated from the report forms, 1.18 roentgens from the film packs, and 0.97 roentgens from the equipment surveys. Estimates of the amount of filtration in the primary beam, obtained from all three sources, were also closely related. In only eight instances did differences between any two sources exceed 1 mm. Estimates of beam diameter, obtained from film packs and equipment surveys, differed by more than one-half inch in only six instances.

Evaluation and Conclusions

The field trial did not include an evaluation of the household interview survey because the National Health Survey had adequately tested this vehicle (10). However, the items added to the household questionnaire to permit followup of reported visits were evaluated.

Interviewers reported no difficulty in obtaining individual height and weight data for each medical X-ray visit reported. Although the reliability of these data was not determined, participating physicians and technicians reported that the availability of height and weight was useful in completing the followup request forms.

Except for one reported visit, the name and address of the X-ray facility was recorded adequately by the household interviewer. For about one-third of the reported visits, supplemental information was readily obtained by the interviewer from the local telephone directory. Household respondents were able to give the location and date of the X-ray visits to mobile units, but not all knew the sponsoring organization. Names of sponsoring organizations were obtained from the local health department, and interviewer instructions will emphasize this point in the proposed national study.

Authorization by the household respondent to permit followup of reported X-ray visits was obtained in all cases except two.

The medical report forms received from hospitals indicated an ability to report all data requested except for phototimed units. Records could not be found for 14 reported visits. Hospital personnel indicated that adding the patient's address to the followup form would help to locate the appropriate records.

Although the number of private medical offices was small, report forms from these facilities indicated an ability to report sufficient data for calculation of required exposure parameters.

Twenty-six of the 28 dental facilities returning completed questionnaires reported adequate data for the required parameters. The quality of response from dental offices included in the field trial was excellent.

Several procedural changes were indicated by the field trial. These included addition of the patient's address to both medical and dental report forms, a separate report form for fluoroscopic examinations, additional instructions for reporting fluoroscopic examinations, addition of inherent, total, and added filtration on the dental report form, and preparation of additional tables for calculating roentgen output.

An evaluation of the film packs used in the field trial demonstrated their value as a device for quality control of data recorded on report forms. Medical and dental facilities indicated few difficulties in exposing the film pack; only four suggested clarification of the accompanying instructions. The packs were able to withstand mail handling except for a small control film which required more secure attachment. The field trial experience also indicated that the values obtained from film pack readings were useful in supplementing reported information.

On the basis of the field trial experience, it was concluded that the methods, procedures, and forms, including the changes indicated, are appropriate for deriving estimates of population exposure to this source of radiation and for obtaining data which are compatible with current research in dose model development.

REFERENCES

- (1) Billings, M. S., Norman, A., Greenfield, M. A.: Gonad dose during routine roentgenography. *Radiology* 69: 37-51, July 1957.

- (2) Great Britain Ministry of Health, Department of Health for Scotland: Radiological hazards to patients. Second report. Her Majesty's Stationery Office, London, 1960.
- (3) Moeller, D. W., Terrill, J. G., Jr., and Ingraham, S. C.: Radiation exposure in the United States. Public Health Rep 68:57-66, January 1953.
- (4) Morgan, R. H.: Radiation control in public health. Public Health Rep 76:571-583, July 1961.
- (5) Windeyer, B. W.: The contribution of diagnostic radiology to population dose. In Proceedings of the 9th International Congress of Radiology. Stuttgart, Germany, 1961, vol. 1, pp. 99-103.
- (6) Brown, R. F., Heslep, J., and Eads, W.: Number and distribution of roentgenologic examinations for 100,000 people. Radiology 74:353-363, March 1960.
- (7) International Commission on Radiological Protection and International Commission on Radiological Units and Measurement: Exposure of man to ionizing radiation arising from medical procedures. Phys Med Biol 2:108, October 1957.
- (8) U.S. Congress: Nature of radioactive fallout and its effects on man. Hearings, Joint Committee on Atomic Energy, Special Subcommittee on Radiation, June 1957, 85th Cong. U.S. Government Printing Office, Washington, D.C., 1957, pp. 859-888.
- (9) Epp, E. R., Weiss, H., and Laughlin, J. S.: Measurement of bone marrow and gonadal dose from the chest X-ray examination as a function of field size, field alignment, tube kilovoltage, and added filtration. Sloan-Kettering Institute for Cancer Research, Division of Biophysics, New York, August 1960.
- (10) Laughlin, J. S., Meurk, M. L., Pullman, I., and Sherman, R. S.: Bone, skin, and gonadal doses in routine diagnostic procedures. Amer J Roentgen 78:961-982, October 1957.
- (11) Miller, W. B., Jr., Rohrer, R. H., and Weens, H. S.: Determination of radiation dose during fluoroscopic procedures with the aid of the fluoroscopic simulator. Radiology 78:237-239, February 1962.
- (12) Ritter, V. W., Warren, S. R., Jr., and Pendergrass, E. P.: Roentgen doses during diagnostic procedures. Radiology 59:238-249, August 1952.
- (13) Sprawls, P., Jr., Miller, W. B., Jr., and Cosper, J. H.: The use of a digital computer in evaluating radiation exposure during fluoroscopic examinations. Given at the 16th Annual Conference on Engineering in Medicine and Biology, Baltimore, Nov. 18-20, 1963.
- (14) Norwood, W. D., et al.: The gonadal radiation dose received by the people of a small American city due to the diagnostic use of roentgen rays. Roentgenology 82:1081-1097, December 1959.
- (15) U.S. Public Health Service: Volume of X-ray visits, United States, July 1960-June 1961. Health statistics from the U.S. National Health Survey. PHS Publication No. 584-B38. U.S. Government Printing Office, Washington, D.C., 1962.
- (16) U.S. Bureau of the Census: U.S. Censuses of population and housing: 1960: Census tracts, Reading, Pa., final report PHC (1)-125. U.S. Government Printing Office, Washington, D.C., 1962.
- (17) U.S. Department of Commerce: Medical X-ray protection up to three million volts. National Bureau of Standards Handbook 76. U.S. Government Printing Office, Washington, D.C., 1961.